

## **Image Processing Application for Cognition: IPAC Architecture and Implementation in Java**

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**Abstract.** An application framework for advanced image processing and visualization is presented. It provides common two-dimensional operators and implements recent developments in the field of image processing as well as original algorithms based on nonlinear partial differential equations (PDEs). It is platform independent and has the capability of extensibility. This objective is achieved by exploiting the object-oriented paradigm. A graphical user interface (GUI) provides processing, analysis and visualization in a highly integrated, easy to use environment. Applications of the developed system to images obtained by the *Spitzer Space Telescope* are demonstrated.

### **1. Introduction**

Continuing rapid advances in image processing and computer vision have produced an arsenal of powerful methods for image enhancement, analysis and segmentation (Bovik 2005). These modern methods have widely been utilized in applied physics, geophysics, biosciences and medical imaging. Some applications of modern techniques to astronomy can be found in Starck & Murtagh (2002). Other techniques, such as wavelets, are discussed by Pesenson et al. (2004, 2005) - filtering based on PDEs, Lenzen, Schindler & Scherzer (2004) - nonlinear diffusion PDE; Borkin et al. (2005, 2007) discusses medical imaging visualization and analysis techniques.

The objective of the ongoing work presented briefly here is to design and implement an image processing framework for astronomical image mining based on innovative algorithms and on the most recent developments in the field of image processing and computational vision.

### **2. Image Enhancement**

Astronomical images usually contain many point sources and, at the same time, extended diffuse structures (supernova remnants, galaxies, etc.). Moreover, point sources (unresolved galaxies or stars) are often imbedded in diffuse structures. Noise removal is one of the steps necessary for source extraction. Applying traditional smoothing methods, such as convolution with a Gaussian or a median filter, is not sufficient for multi-scale astronomical images. Indeed, such approaches are effective at removing noise but also have the unwanted side-effects of eliminating tiny point sources, smearing more prominent ones,

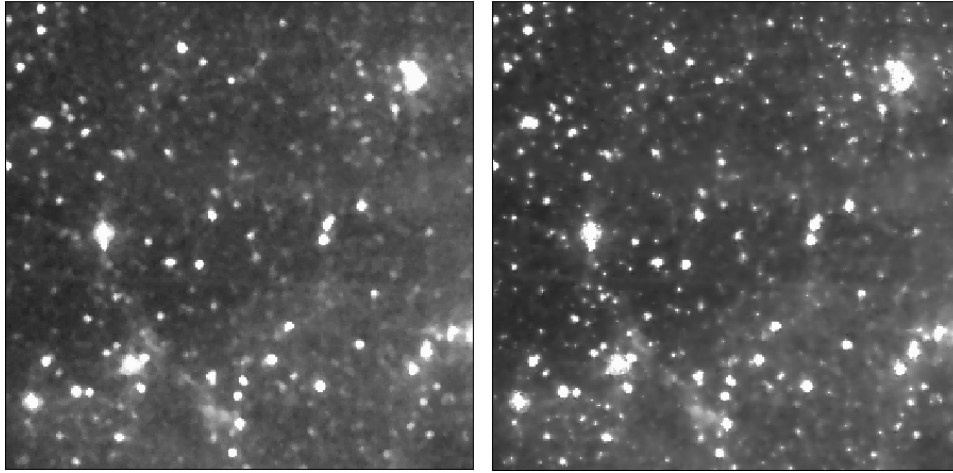


Figure 1. Linear filtering vs. nonlinear PDE-based filtering; signal to noise ratio (SNR) has increased but many faint point sources are gone (*left*); SNR has decreased while point sources and the super nova remnant are preserved (*right*)).

and blurring the boundaries and edges of extended structures. The trade-off between smoothing and preserving objects is inevitable. A balance between these two desirable, but incompatible objectives depends on the specific task and one can not claim the existence of a universal solution: “...mine eye is in my mind”. We applied filtering based on a nonlinear diffusion-reaction equation to an image of G11, observed as part of the GLIMPSE Legacy Survey (see Figure 1) and to an image of the supernova remnant W28 (G6.4-0.1), obtained by the *Chandra X-ray Observatory* (see Figure 2). Technical details and statistical assessment of the processing can be found in Pesenson et al. (2005).

### 3. Framework, Object-Oriented Design, Layered Architecture

An application framework consists of processing modules, data, and an interactive interface and has the capability of extensibility. Developers and users alike have realized that there is more to creating an application than simple programming, and the objective is achieved here by exploiting the object-oriented paradigm. By breaking up the process into layers, with every layer containing many packages, we achieved a more flexible and reusable structure of the application. There are four major layers in our framework: the User Interface Layer is responsible for showing it to the user and for interpreting the user’s commands; the Application Layer defines the jobs the software does; the Domain Layer is responsible for representing concepts of image processing; and the Infrastructure Layer provides generic technical capabilities. The essential principle is that any element of a layer depends only on other elements in the same layer or on elements of the layer beneath it. The layered structure leads to a flexible and reusable structure of the application. With this approach, developers only have to modify or add a specific module, rather than have to rewrite the entire ap-

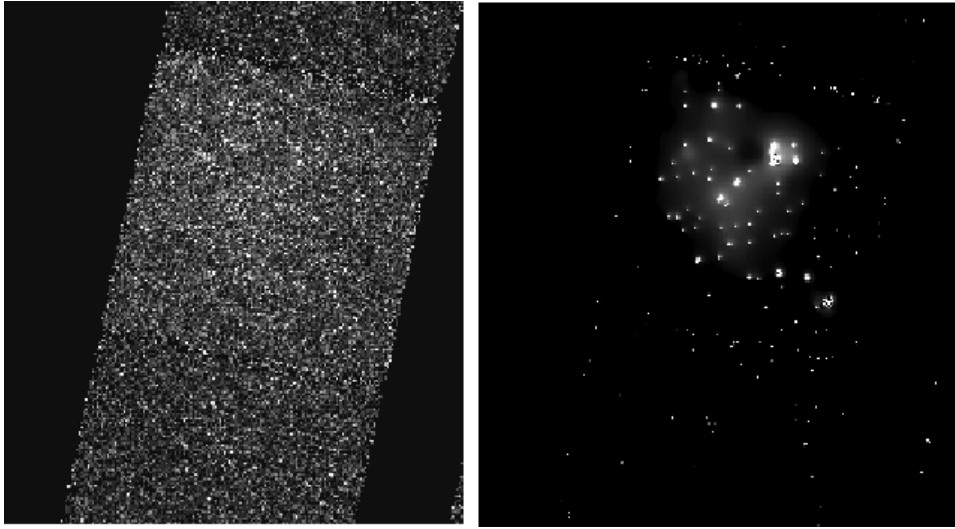


Figure 2. Raw image (*left*) and processed image (*right*). The SNR has been increased and point sources, including the ones embedded in a super nova remnant, have been preserved.

plication, if they decide to change algorithms or scale up. Connections between layers are based on various object-oriented design patterns (Grand, 2002).

#### 4. Main Features of the Application Framework IPAC

Flow or sequence-dependent module processing has been implemented. Multiple runs with different settings are allowed during a session. The user can visually and statistically compare outputs from different runs, store parameter settings and perform I/O (FITS files/stacks, tables). A large variety of plots can be generated (based on JFreeChart): line charts, scatter plots, pie charts, bar charts, 3D plots, etc. Images and plots can be saved in different formats. The GUI is very intuitive. The visualization provides many powerful features including display and overlay images from various digital sky surveys, table-image interaction, different grids, tables, distance tool, three-color display and opacity control. The interface for setting parameters for the nonlinear diffusion module and overlaying images capability is shown in Figure 3. A detailed description of the GUI can be found in Pesenson et al. (2006). A powerful tool, ImageJ, written in Java for biomedical image processing has been developed by National Institute of Health. It provides many powerful capabilities for image processing but does not suit astronomical needs. It does not include the world coordinate system - WCS, and there is no sequence-dependent module processing.

#### 5. Conclusion

A platform-independent application framework for astronomical image processing, analysis and visualization has been presented. It provides common 2-D

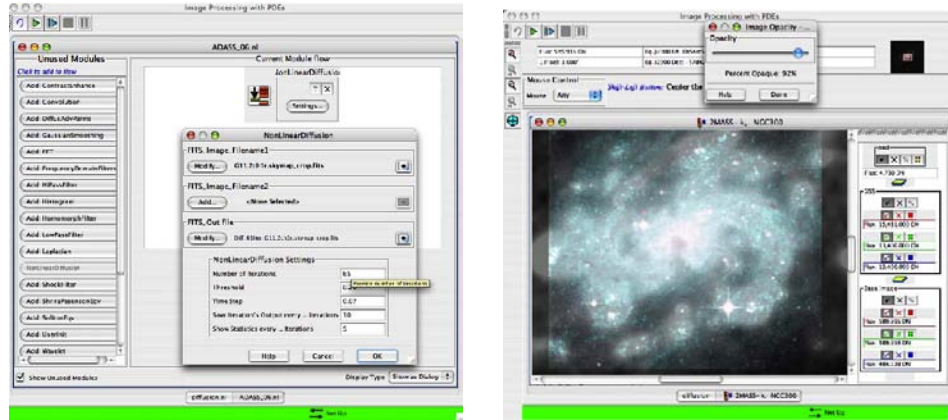


Figure 3. Settings for nonlinear diffusion filter (*left*); viewing output images and overlaying images (*right*).

operators as well as techniques recently developed in the field of image processing, and also implements original algorithms based on nonlinear PDEs. The application framework provides an integrated environment for interactive astronomical image enhancement, analysis and segmentation and is based on modern developments in computer vision and image processing.

Future work includes adding more modules for filtering, edge detection and segmentation, pattern recognition, quality assessment, spectra, and statistics.

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